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DEPARTMENT OF COMMERCE
U. S. COAST AND GEODETIC SURVEY
E. LESTER JONES, SUPERINTENDENT

HYDROGRAPHY

CONSTRUCTION AND OPERATION OF THE WIRE DRAG

By

J. H. HAWLEY
Hydrographic and Geodetic Engineer

Special Publication No. 56

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INTRODUCTORY.

The Coast and Geodetic Survey began the survey of our coastal waters with the wire drag in 1904 and has carried on the work continuously since that time. The first apparatus was patterned after the drag used at that time by the Corps of Engineers, United States Army, on the Great Lakes, which in turn was an improved form of the long-rope sweep introduced by French hydrographers. The Survey has gradually developed and perfected the equipment and methods of operation used for this work until at the present time the improved wire drag is a very efficient mechanism when skillfully operated.

The earlier developments of the drag to meet the requirements for coast work are described in Appendix 6, Report of the Superintendent of the Coast and Geodetic Survey for 1905, and in Appendix 7 of the report for 1907. The Description of Long Wire Drag, published in 1910, and the revised edition, published in 1914, give the general details concerning equipment and methods used at that time. This last edition is now exhausted and, as a number of improvements and changes in practice have been made since the date of its publication, it will not be reprinted.

The Survey receives frequent requests for information concerning the details of its wire-drag work from foreign countries, other organizations of our Government, and from private interests. To supply such information to all those who may be interested, by describing in a comprehensive manner the equipment and methods of operation used at the present time for wire-drag work, is the object of this publication. It is illustrated by photographs and drawings of equipment used on the Atlantic coast. A description of minor modifications that have been found necessary in order to meet special conditions in Alaska may be had in Special Publication No. 34 of the Coast and Geodetic Survey, and a general discussion concerning wire-drag work on the Atlantic coast is given in Special Publication No. 29.

PURPOSE OF THE WIRE DRAG.

The wire drag was adopted as a means of supplementing standard methods of hydrographic surveying, whereby it would be possible to discover and chart all obstructions of small extent, such as pinnacle rocks, bowlders, sharp ledges, and coral formations. Such obstructions are especially dangerous to navigation, and it had become evident that it is only by chance they are found during the course of an ordinary hydrographic survey by which soundings are obtained at only certain points over a given area.

As a result of successive improvements the drag is now adapted to the different requirements of three classes of work—first, to determine whether an apparently open sea is free from obstructions; second, to find all obstructions in a shoal area; and third, to develop the maximum safe depth in a channel.

The drag has been used on the coasts of New England, Alaska, Florida, Porto Rico, the Pacific coast, and in the approaches to the Panama Canal. That it fulfills its purpose is shown by the fact that, in the 4,000 square miles of water area dragged, over 3,500 uncharted obstructions have been discovered.

CONSTRUCTION.

The wire drag (fig. 1) consists of a wire, called the bottom wire, maintained at any desired distance below the water surface by weights suspended by cables from buoys that float on the surface. This wire is made up in 100-foot units, to each end of which is fitted a special socket. A number of units, sufficient to make the desired length of drag, are connected by swivels. The weights are attached to the wire at regular intervals of from 300 to 600 feet, depending on the nature of the work and the total length of drag.

The cables, or uprights, as they are called, connecting weights and buoys are graduated to feet and pass through a central pipe to a drum on the top of each buoy, so that the distance of the wire below the surface can be adjusted at any time to conform to the bottom contours, as shown by lead-line surveys, and to the rise and fall of the tide.

Metal floats that will just support the weight of 100 feet of wire are attached at each swivel connection between the weights. When the drag is towed and the wire is under tension their action is negligible, but when the drag is not under way they keep the wire from sagging between weights and catching on the bottom.

For the sake of clearness the following definitions of terms used in wire-drag work are given:

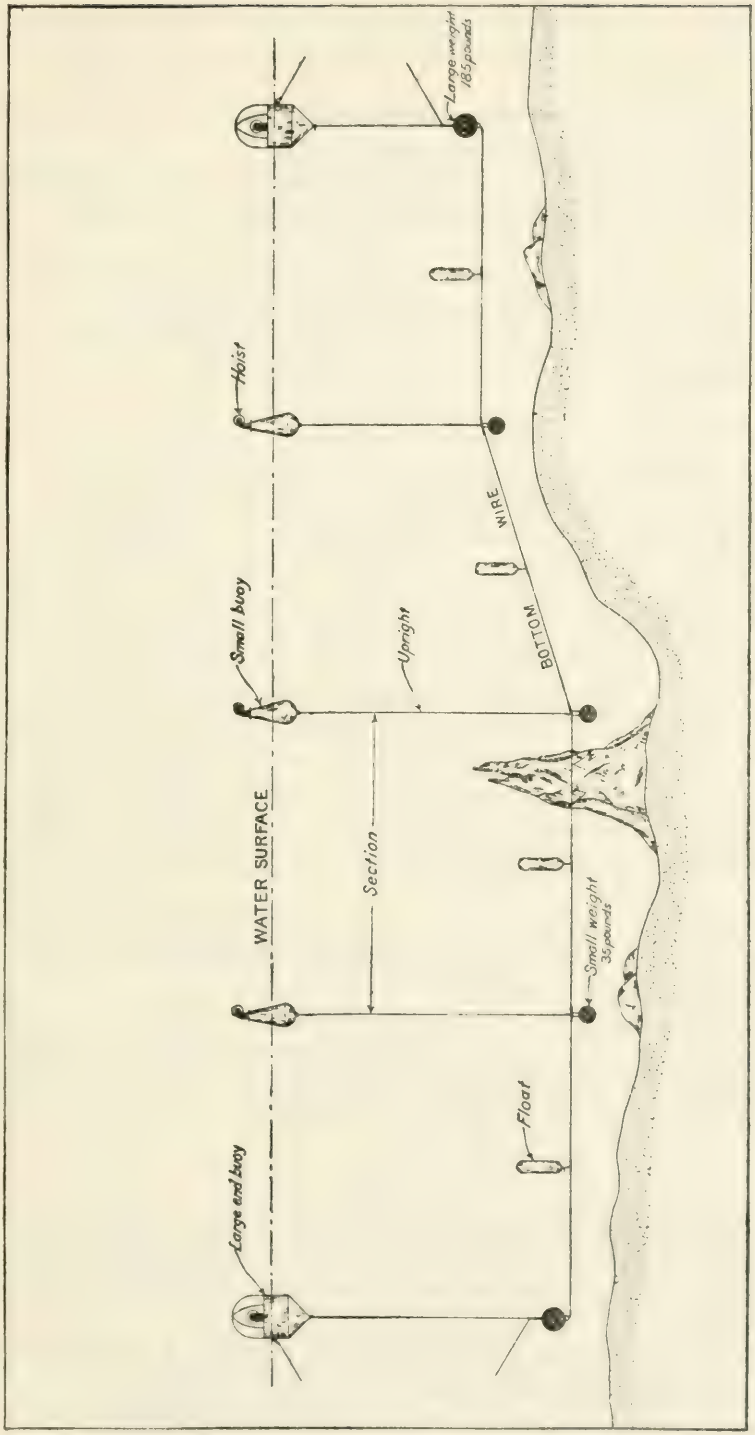


FIG. 1.—WIRE-DRAG CONSTRUCTION DIAGRAM.

Length of upright.—The distance from the water line of the buoy, when the drag is at rest, to the point of attachment of the upright to the bottom wire.

Drag depth.—The distance between the water surface and the bottom wire when drag is under way.

Effective depth.—The distance between the plane of reference, such as mean low water, and the bottom wire when drag is under way.

Length of drag.—Length of bottom wire between ends of drag.

Section.—That part of the drag between two uprights.

Unit.—The part of the bottom wire between sockets which breaks its continuity.

BOTTOM WIRE.

Double-galvanized, 7-strand, steel wire, one-eighth of an inch in diameter, with a tensile strength of about 2,000 pounds, is used for the bottom wire. This wire, which can be obtained in any continuous length desired, is cut up into 100-foot lengths and a special drop-forged, open socket (fig. 2) is attached at each end by the Roebling method. In this method the end of the wire is passed through the socket and the wire is seized with sail twine at a distance back from the end equal to the length of the butt of the socket. The wires beyond the seizing are then unstranded and bent out radially from the seizing. After removing the galvanizing from these wires by immersion in acid, they are drawn back flush into the socket and the butt is filled with pure commercial zinc melted in a ladle. An improvement on this method is made by crimping the ends of each wire.

In regions of strong currents, where heavy boats are used, a stronger wire may be required, in which case wire three-sixteenths of an inch in diameter may be used.

Bottom wire units are connected by one-fourth inch galvanized, drop-forged, steel swivels. To facilitate attachment of floats and weights, a link of one-fourth inch round iron, about 3 inches long, is welded into one of the eyes in each swivel.

LARGE AND SMALL WEIGHTS.

The shape and dimensions of the large weight, which weighs 180 pounds, are shown in figure 2. The bodies of all weights are cast-iron spheres, with one flat surface to prevent rolling about deck in a seaway.

The small weight (fig. 2) weighs 35 pounds. For attachment to the wire one side of the staple is formed by a hinged, brass rod. A slotted sleeve slides on this rod and fits into a section of galvanized

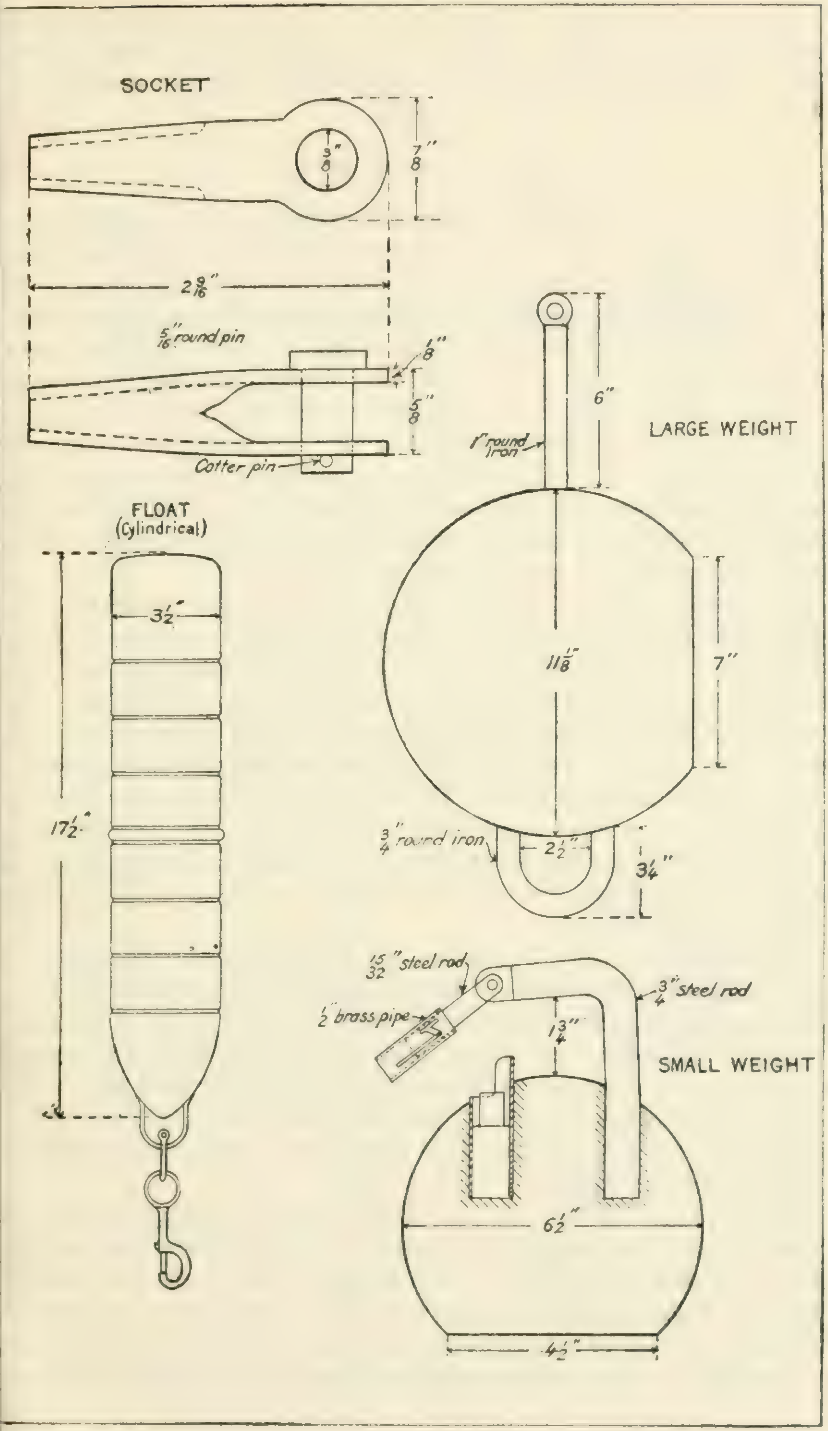


Fig. 2.—SOCKET, FLOAT, LARGE AND SMALL WEIGHT.

pipe, cast in the sphere. When the pin in the rod engages the right-hand slot the sleeve can be lifted far enough to swing clear. When the staple is closed the sleeve is turned so that the pin engages the left-hand slot, which locks the staple.

LARGE AND SMALL BUOYS.

The design and dimensions of the large buoy, which weighs about 180 pounds, are shown in figures 3 and 4. This buoy is constructed of No. 17 galvanized, rustproof iron, except the top plate, which is of three-sixteenths inch galvanized boiler plate. All joints are either riveted and soldered or electrically welded to make the buoy absolutely water-tight, and it is strengthened against crushing by internal bracing. For passage of the upright, a central galvanized pipe, $1\frac{1}{2}$ inches in diameter, passes through the buoy and extends through the top and bottom. This pipe is held in place by internal and external lock nuts, and its projecting ends are threaded to hold bell-shaped leaders. When in use the buoy is protected by rope netting in which an eye is provided for towline attachment.

The essential parts of the hoist (fig. 4) are the iron standard, with a hole in its base to fit over the pipe, and the upper and lower shafts with brass 4-to-1 reducing gears. The upright winds on the lower shaft, which is converted into a drum by two brass flanges. The hoist is operated by turning the upper shaft with a removable iron crank. This shaft is provided with a brass rachet that is engaged by a brass dog to lock the hoist. The hoist is attached to the buoy by six machine bolts that screw into threaded holes in the top plate. Wooden washers are inserted between the hoist and buoy top on all buoys. A protective framework of strap iron is provided on the top of the large buoys.

The small buoy (figs. 3 and 4), which weighs about 60 pounds, is constructed of rustproof iron, three thirty-seconds of an inch thick, with a top of one-eighth inch boiler plate. All joints are electrically welded to make the buoy water-tight. It is provided with internal bracing, and a central, extra-heavy, galvanized three-fourths inch pipe, as for the large buoys. After the construction of the buoy is completed it is galvanized. This buoy must stand submerging to 50 feet without crushing.

The iron frame of the hoist is curved in such a manner that a line projected from the center of the pipe will fall halfway between the drum core and the outside of the flange. The inside distance between the frame uprights is 2 inches. The drum, which is keyed to the shaft, consists of a hardwood core, $1\frac{7}{16}$ inches wide and 3 inches in diameter, to which galvanized-iron flanges, 7 inches in diameter,

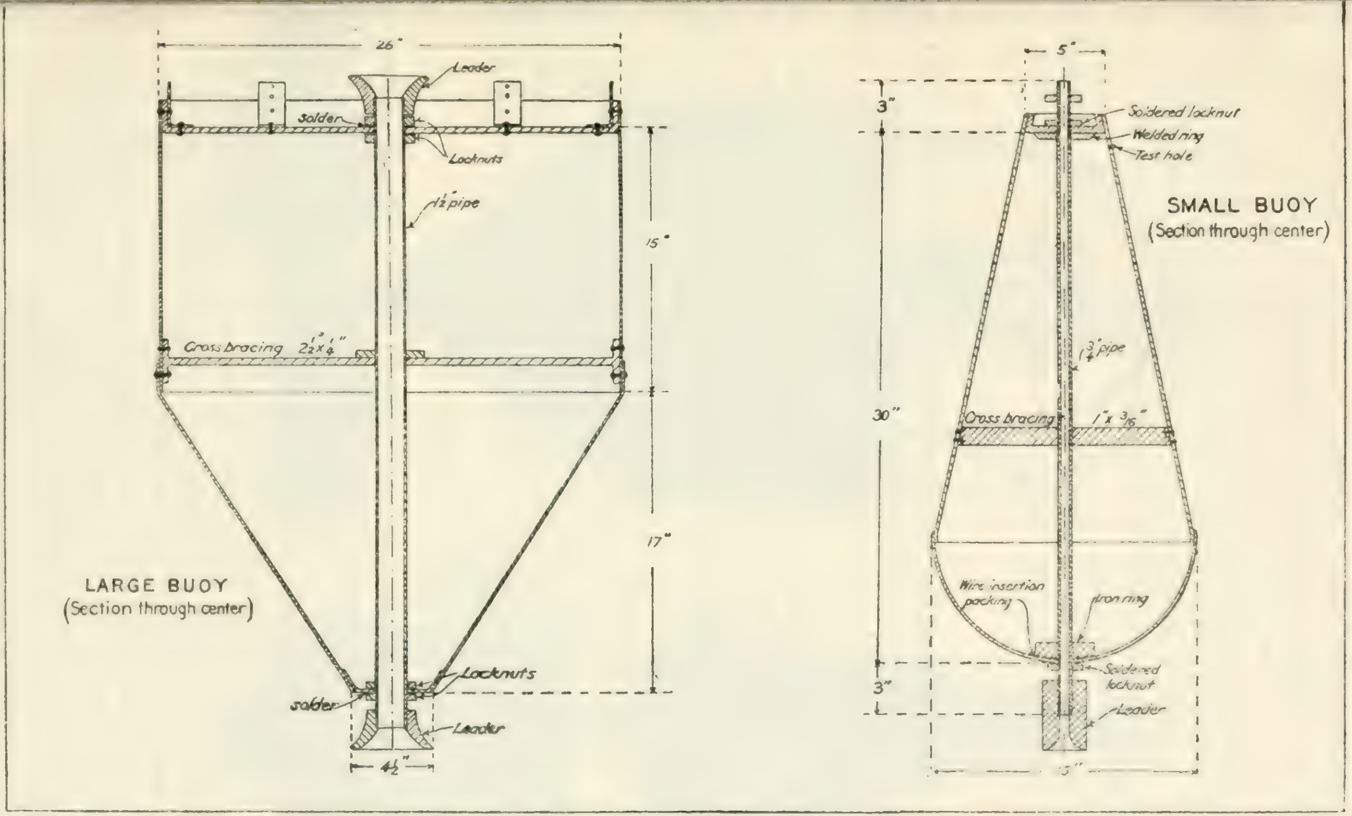


Fig. 3.—DESIGN FOR LARGE AND SMALL BUOYS.

are attached by countersunk screws. A ratchet and locking dog is provided on each hoist. All dogs have spring pins that engage a hole in the frame and hold the dog against the ratchet.

On the bottom projecting pipe is screwed a case hardened steel leader, with a bell-shaped mouth to prevent chafing of the upright. This leader should be about 4 inches long and 2½ inches in diameter, as it must have enough weight to steady the buoy in the water.

A rope lanyard is attached to each buoy to secure the buoy when making depth changes.

The old bucket type of small buoy is still used to some extent, but the later type, described above, has many points of superiority.

FLOATS.

During the past few years wooden floats have been superseded by hollow, metal floats of various designs. The one that has proved to be most satisfactory is described below, and may be considered as standard.

This float is shown in figure 2. It is constructed of aluminum plate and is hollow. It is strengthened by corrugations and an internal web, as it must stand submerging to 200 feet without crushing. The float is attached to the bottom wire by a No. 1 swivel-eye, tinned, harness snaphook, shackled to the small bale at the end of the float with a one-fourth inch galvanized, screw anchor shackle.

A welded iron float, which, of course, is much heavier, has also been used, and, if metal floats can not be obtained, the old-style cedar float can be used to advantage with drag depths of 50 feet or less. Wooden floats must be treated before using by boiling in oil or tallow.

UPRIGHTS.

For the small-buoy uprights three-sixteenths inch, extra-flexible, steel-wire rope is used. This rope consists of 6 strands of 19 wires each. The buoy drum will hold 65 feet of this rope, and the uprights are consequently made up in this length. The rope is cut in 67-foot lengths to allow for spare rope, and a five-sixteenths inch galvanized, drop-forged swivel is attached to one end of each length with a served clove hitch. The reference point on all buoys is the top of the central pipe, and it is therefore necessary to begin the graduation at a distance from the swivel equal to the height of the pipe top above the water surface when the drag is at rest (see definition of length of upright). Beginning at this point the upright is painted in 10-foot divisions—black, white, red, blue, black, white, red, in the order named. Each division is subdivided into 2-foot lengths by inserting four colored rags in the same order, and intermediate feet are marked by serving with sail twine. With this system of gradua-

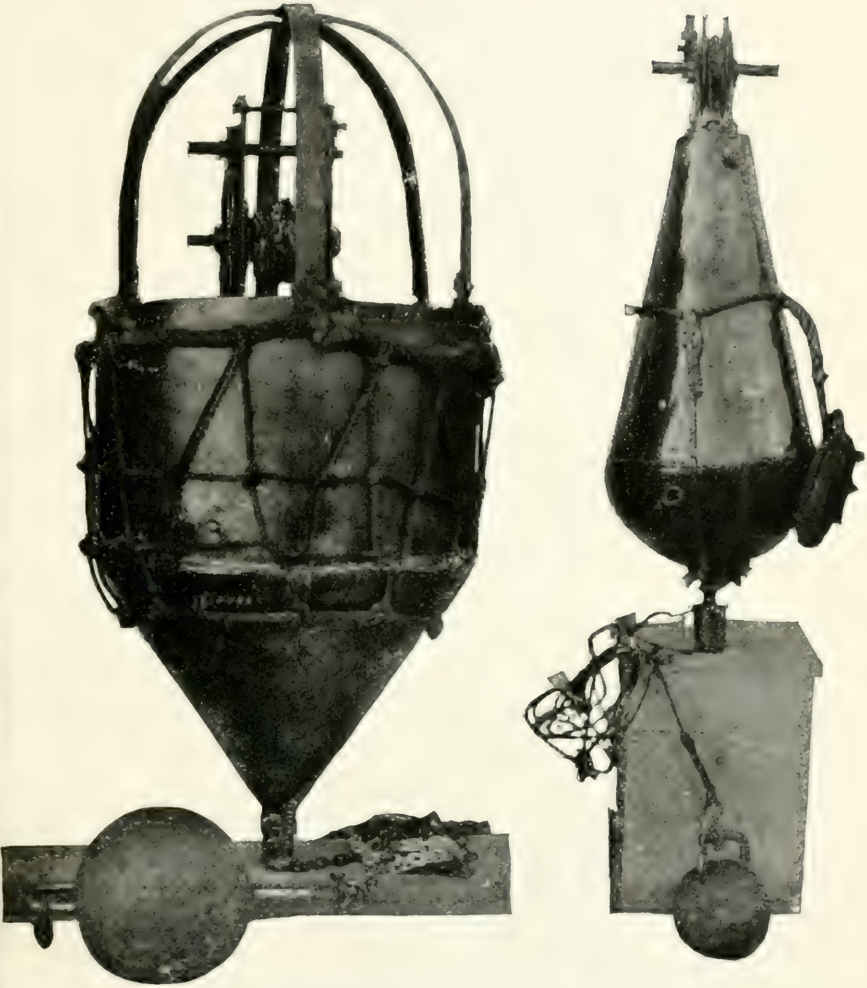


Fig. 4.—LARGE AND SMALL BUOYS, WEIGHTS, AND UPRIGHTS.

tion, bringing the junction of the red and blue divisions to the reference point gives an upright length of 30 feet: the red rag on the blue division gives a 36-foot upright, etc.

For drag depths over 65 feet, supplemental, fixed-length uprights are attached to the painted uprights. These uprights have a harness snap attached to one end and a swivel to the other. Their length depends on the nature of the work. On the Atlantic coast, where the maximum drag depth is 100 feet and the tidal range not over 15 feet, two complete sets, one 20 and the other 30 feet long, are provided.

The large-buoy upright is made of three-sixteenths inch galvanized cable chain. It it graduated in the same manner as the small uprights, except that as the drum will hold only 45 feet of chain the two lower colored divisions are replaced by a 20-foot length of five-sixteenths inch steel-wire rope, unpainted. To correspond with the small uprights, the first colored division on the chain is therefore red. This upright is attached to the top of the rod on the large weight, and it has been found that when dragging the weight and rod form an angle of 20° with the horizontal. The index correction for the large upright is therefore obtained by subtracting one-third of the total length of the weight from the height of the reference point above the water surface.

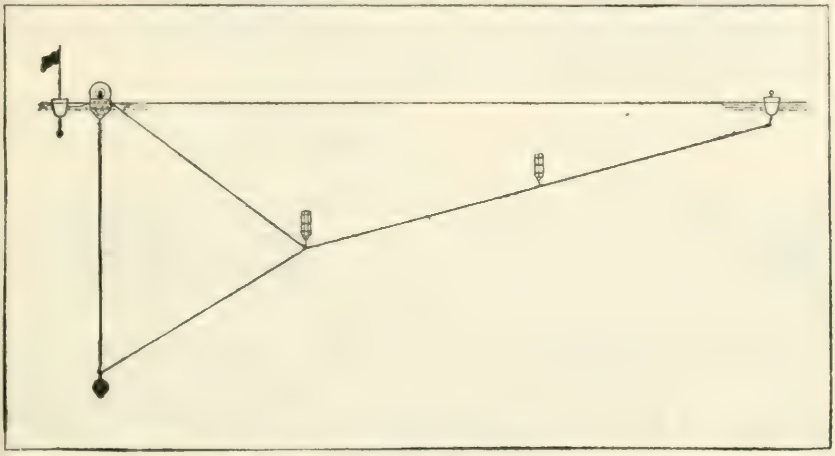


Fig. 5.—STEEL TOWLINE ARRANGEMENT.

TOWLINES.

The towline (fig. 5) at each end of the drag consists of two parts, one of rope and one of metal. The rope towline will be described later. For the metal towline galvanized, steel-wire rope, five-sixteenths inch in diameter, is used. This rope is made up in 100-foot units, at each end of which an eye-splice is laid over a wire-rope thimble. A five-sixteenths inch swivel is inserted in one eye of each unit, and the units are connected by five-sixteenths inch shackles. The towline consists of a bridle and a straightaway. The object of the straightaway and the lower part of the bridle is to transmit the tension from the towing launches to the drag, while the upper part of the bridle serves to keep the large buoy directly over the weight and to insure an invariable towline base. For attachment to the large buoy, a No. 5 swivel-eye, galvanized-iron snaphook is shackled to the free end of the upper bridle. Floats are attached to the towline for the same purpose as on the bottom wire. A towline from 300 to 500 feet long is used, depending on conditions, which will be discussed later.

DRAG LENGTHS.

Lengths of drag under 3,000 feet are rarely used except in channels with less width than this. The following table gives information relative to drag lengths in ordinary use:

Length of drag.	Length of section.	Effective width.	Conditions.
	Feet.	*Feet.*	
Less than 3,000 feet	300		Narrow channels.
3,000 feet	300	2,700	Very broken bottom.
4,000 feet	400	3,600	Broken bottom.
5,000 feet	500	4,500	Fairly clear bottom.
6,000 feet and over	600		Deep water.

Lengths of drag for deep-water work are commonly 9,000, 12,000, and 15,000 feet, depending on the area to be covered and the current velocity. A drag 24,000 feet long, towed by four launches, has been used; but the above lengths are about all that can be handled with the two towing launches used by each party.

LIST OF PARTS.

The following list gives the amount, cost, and life of equipment necessary for a 15,000-foot drag with no spare parts. Costs have increased considerably during the past few years and always depend somewhat on the locality where the equipment is obtained; likewise, the life of equipment depends on the nature of the work and other conditions, so that the data under these headings is given only to convey a rought idea concerning them. The amount of spare equipment necessary depends on the nature of the work and the distance of the party from dealers and from other parties. Under ordinary conditions, when the maximum length is used infrequently and replacement can be made without undue delay, a 100 per cent surplus of large buoys, large weights, wire rope and chain, and a 10 per cent surplus of other material will probably be ample.

Quantity.	Article.	Cost.		Life.
		Unit.	Total.	
15,000 feet	Bottom wire	$0.012	$180.00	12 months.
2	Large weights	12.00	24.00	Indefinite.
24	Small weights	6.00	144.00	Do.
2	Large buoys, complete	80.00	160.00	24 months.
24	Small buoys, complete	40.00	960.00	Do.
6	Buoy cranks	1.50	9.00	12 months.
145	Floats	3.00	435.00	Do.
3,000 feet	$\frac{3}{16}$-inch wire rope (uprights)	.07	210.00	6 months.
1,500 feet	$\frac{3}{16}$-inch wire rope (towlines)	.08	120.00	Do.
100 feet	$\frac{3}{16}$-inch chain	.12	12.00	18 months.
300	Sockets	.30	90.00	24 months.
151	$\frac{1}{4}$-inch swivels with links	.35	52.85	Indefinite.
100	$\frac{5}{16}$-inch swivels	.30	30.00	Do.
200	Harness snaphooks	.15	30.00	12 months.
2	No. 5 snaphooks	.60	1.20	3 months.
150	$\frac{1}{4}$-inch shackles	.20	30.00	Indefinite.
12	$\frac{5}{16}$-inch shackles	.25	3.00	Do.
12	$\frac{7}{16}$-inch shackles	.30	3.60	Do.
30	Wire-rope thimbles	.04	1.20	6 months.
	Rough total		2,500.00	

All wire rope, chain, and fittings must be galvanized.

LAUNCHES.

The drag is towed by two launches, the launch from which the work is directed being called the "guide launch," while the other is called the "end launch." A smaller launch is used as a tender to patrol the drag, change its depth, clear it from shoals, remove fishing gear from its path, etc. One or two small dinghies, equipped with engines, are used chiefly to sound on shoals, though they may assist the tender with other work at times.

GUIDE AND END LAUNCHES.

A description of the launch designed by the Survey for its drag work (fig. 6) will give an idea of the requirements. This launch has a flush deck with a pilot house forward. It is strongly constructed of southern pine. It has quarters forward for two men and a large afterhold for storage of equipment when the party changes headquarters. Two important features of a satisfactory wire-drag launch are an arrangement for one-man control when setting out and taking in drag, and the location of the exhaust at some point where the exhaust vapors will not interfere with observing and plotting angles. The dimensions of the launch are as follows: Length, 60 feet; beam, 14 feet; draft, 3 feet 7 inches; depth, 7 feet; freeboard, forward, 6 feet 9 inches; freeboard, aft, 4 feet. It is propelled by two 40-horsepower, 4-cycle, 4-cylinder, gasoline engines. Power for towing is reduced by using only one engine; while on the runs to and from the work,

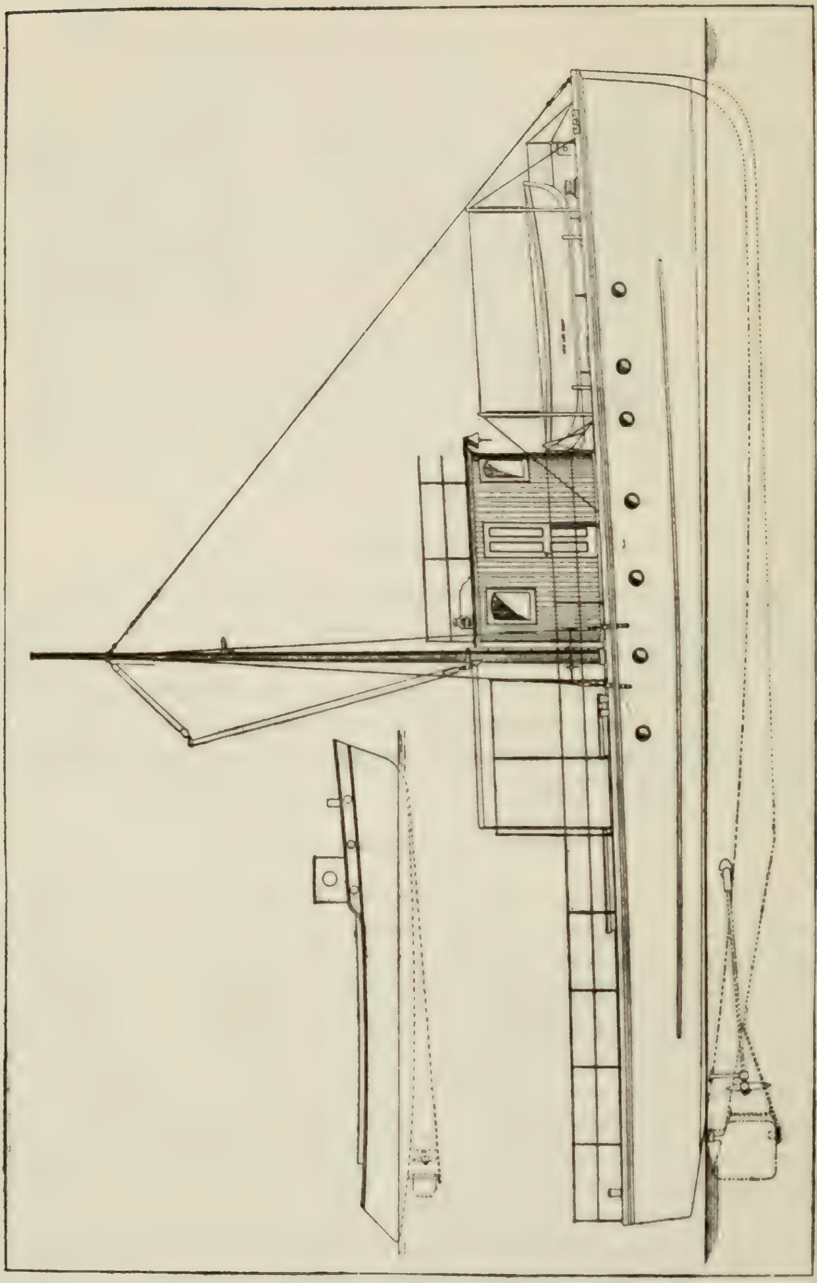


Fig. 6.—OUTBOARD PROFILES OF WIRE-DRAG LAUNCH AND TENDER.

both engines are available to increase the speed and reduce the unproductive part of the day's work. This launch can also be used as an end launch, or a smaller launch of the same type may be used. The length of the end launch, however, should not be less than 40 feet and the speed should equal that of the guide launch.

TENDERS.

The tender should be an open launch of the ablest possible type, as it must stand the same weather as the larger launches and be capable of replacing one of them in emergencies. The outboard profile of the tender adopted by the Survey is shown in figure 6. This launch has a small cruiser cabin forward, a self-bailing cockpit, and is heavily constructed. It is propelled by one 28-horsepower, 4-cycle, 4-cylinder, gasoline engine. Its dimensions are as follows: Length, 30 feet 2 inches; beam, 7 feet 8 inches; draft, 3 feet 2 inches. The sounding tenders should be of the dinghy type, 14 to 16 feet long. They are propelled by 2-horsepower gasoline engines and are equipped with rowlocks and oars.

OPERATING EQUIPMENT ON LAUNCHES.

The greater part of the operating equipment is installed on the towing launches. This equipment consists of power reels, an arrangement of platforms and rollers at the bow and stern over which the wire passes, signaling apparatus, buoy rack, drafting table, and miscellaneous items.

GUIDE AND END LAUNCH EQUIPMENT.

The arrangement of equipment on the guide launch is shown in figure 7. The essential parts of the power reel (fig. 8) are the drum, divided into two compartments for towline and wire and securely keyed to a shaft which carries two 27-tooth sprockets keyed to its outboard end; a supporting frame of wrought angle iron suitably braced, which carries bearings for the shaft; an external contracting brake, with its drum secured to the reel drum; and the various operating levers. Handles are attached to the inboard drum flange for turning the reel by hand, and holes are provided in the outboard flange for attachment of similar handles in case of engine failure. Power is transmitted to the reel through a jackshaft, which is in two parts, connected by a one-way clutch, and is supported by three floor-stand bearings bolted to the deck. On the inboard end of this shaft is keyed a 27-tooth sprocket, which is connected by a sprocket chain to a sprocket on the shaft of a 5-horsepower, horizontal, double-flywheel type, gasoline engine in the hold. On the outboard end of

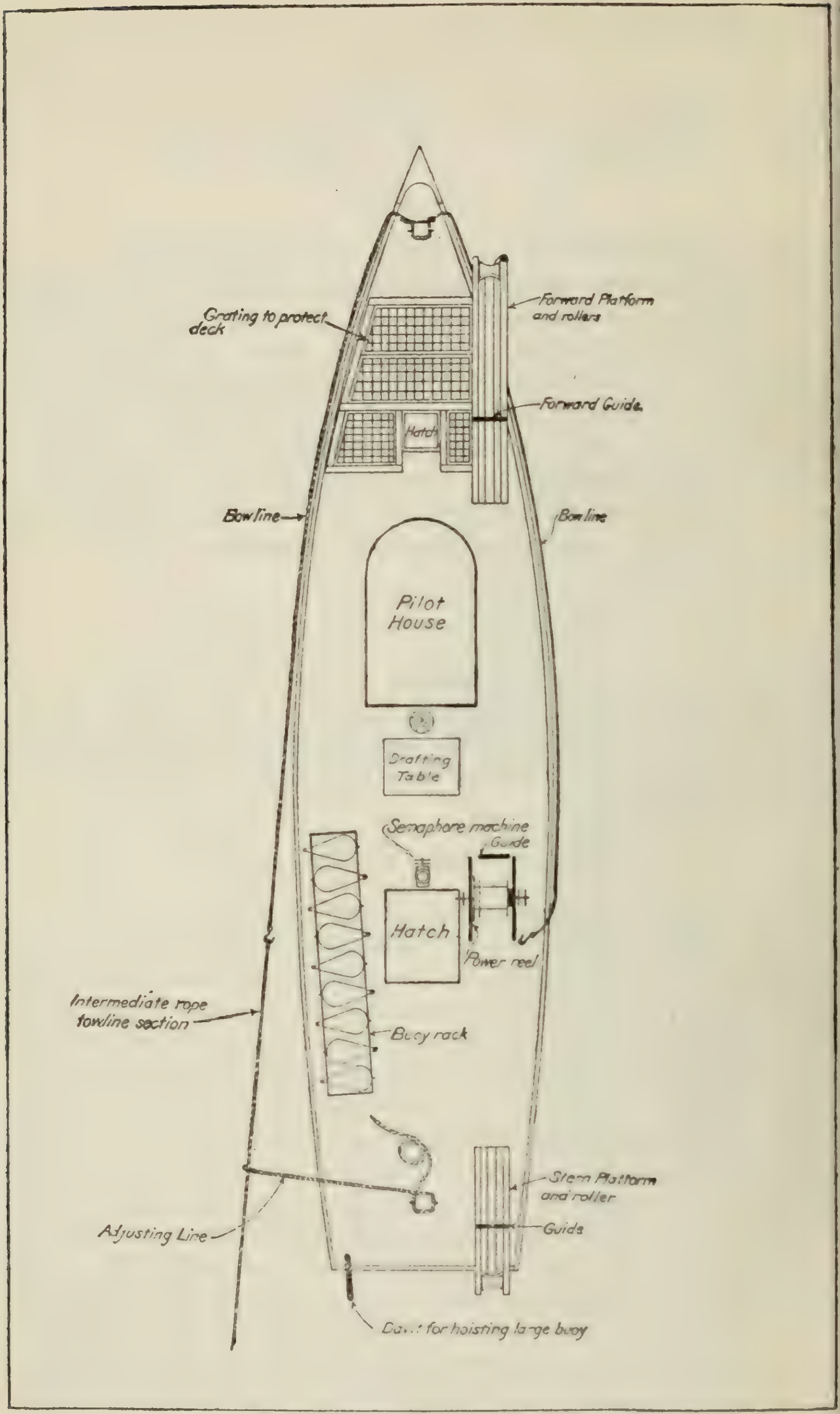


Fig. 7.—ARRANGEMENT OF EQUIPMENT ON GUIDE LAUNCH.

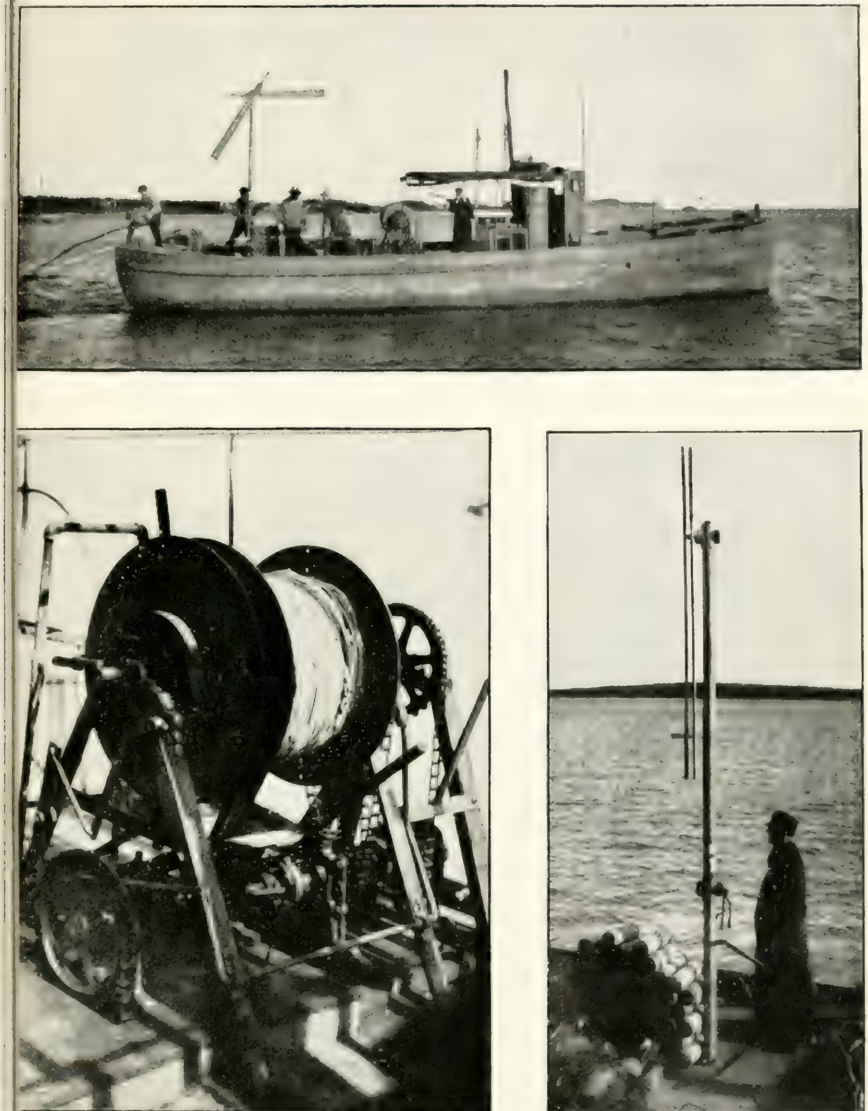


Fig. 8.—GUIDE LAUNCH SETTING OUT DRAG; POWER REEL; SEMAPHORE MACHINE.

this shaft two sprockets, with 9 and 20 teeth, respectively, turn freely. Between these sprockets, which are connected with corresponding upper sprockets by chain, is a double-jaw clutch sliding on a key on the shaft. By means of a lever this clutch can be placed in a neutral position or engaged with a jaw cast on each of the sprockets. When this clutch engages the small sprocket and the one-way clutch is thrown in, the reel drum turns at about 70 revolutions per minute. When it engages the large sprocket the drum turns from 140 to 160 revolutions per minute. To stop the reel, the one-way clutch is thrown out and the brake applied. All levers are brought close together back of the reel on the outboard side, so that one man can operate them. The brake-lever arrangement is considerably simplified by attaching the brake drum to the outboard flange of the reel drum. No. 62 pressed-steel sprocket chain is used. In constructing this reel care must be taken to insure considerable bearing surface for all keys, and the reel, jackshaft, and engine must be securely bolted in place.

The Survey has just begun the use of twin-screw boats, and it is believed that the reel can be improved by using power from one of the main engines, thus eliminating the hoisting engine. A variable-speed, friction transmission that will also do away with the jackshaft is being considered.

The platforms holding the rollers should be constructed of durable wood and securely bolted to the deck. Timbers 4 inches square, spaced about 18 inches from center to center, form the fore and aft sides of the platforms. The horizontal rollers may be of hardwood or of pipe with end plugs and should have a diameter of at least 4 inches. Probably the most satisfactory roller is specially constructed of cast iron. It is hollow and has a center diameter of about 6 inches, increasing gradually to 10 inches at the ends. To prevent the wire from passing over sharp corners, curved horizontal and vertical outboard fenders of pipe or hardwood are installed on the forward platform. For protection of floats, the forward platform should be padded with old rope or coir matting. At a distance of about 3 feet back from the after roller and 6 feet from the forward roller inverted U-shaped guides of 1-inch pipe or solid iron are provided to prevent the wire, when slack, from flying off the platforms. A similar guide is installed just forward of the reel.

An automatic winder, based on the principle of the sewing-machine bobbin winder, has been devised to guide the wire evenly on the reel when taking in drag. With the one-eighth inch bottom wire this winder is not essential.

A semaphore machine is used for signaling. This machine consists of a 3-inch galvanized-iron pipe about 8 feet long, to each end of which is attached a standard iron cross. The horizontal vents in each cross are plugged and bored to form shaft bearings. Each cross holds a double shaft, a sprocket being keyed to each shaft. Corresponding upper and lower sprockets are connected with bicycle chain. The upper shafts project to the front of the machine and carry wooden arms 6½ feet by 8 inches, counterweighted. The lower shafts are reversed to project to the rear and carry iron operating levers. All sprockets are of the same size, and the general design is such that an arm assumes any position in which its operating lever is placed. The machine is supported by a base pipe extending from the lower cross down through the deck to a socket on the keel. This pipe turns freely, so that the machine can be turned to face in any direction. One side of each arm is painted red and the other side white, so that the machine can be seen against any background.

Rope 1¾ inches in circumference is used for the towline, which is in two parts. A bowline is attached to the bow and extends to a point about 10 feet aft of amidships on each side of the launch. A steel hook is spliced to the after end of each bowline. An intermediate section (about 35 feet long for a 60-foot launch), with an eye spliced in each end, extends from the end of the steel towline to one of the bowline hooks. An adjusting line of 1¾-inch rope, with a No. 5 snaphook spliced in one end, is used to distribute the towing strain and to lift the towline clear of the propeller when it lies close alongside. In order to handle the drag, it is sometimes necessary to tow from the bow. With this arrangement the strain can be applied to any point on the launch, and the drag can be towed from either side by attaching the intermediate section to the proper bowline hook.

If the drag catches on a shoal when working in a strong current, it is sometimes desirable to avoid excessive strains by immediately detaching the towline. For this purpose a tripping device may be provided at one end of the intermediate section. As the action of such a device, however, is not entirely satisfactory, it is probably best, under ordinary working conditions, to dispense with it, shackle the rope and steel towlines together, and provide a means for cutting the intermediate section in emergencies.

The buoy rack, which is simply a framework of wood, is constructed to hold nine small buoys, the number commonly used. A small davit for hoisting the large buoy aboard is provided. The launch should be equipped with an ample supply of swivels, shackles, and other fittings, pliers, chain hooks, buoy cranks, lead lines, etc., and should carry plenty of spare buoys, weights, bottom wire, etc.

The equipment on the end launch is similar to that on the guide launch, except that a semaphore machine is not essential and only a small amount of spare equipment need be carried. If a semaphore is not provided, the launch should carry wigwag flags and an answering device consisting of a collapsible black and white cylinder operated by a rope pull.

EQUIPMENT ON TENDERS.

The large tender should carry a spare buoy and weight, several bottom wire units, spare fittings, lead line, drag tester, buoy cranks, grapnel, shoal-marking buoy, sextant, record book, and a copy of the signal code. On the New England coast a power lobster-pot hoist may be installed for removing fishing gear.

The sounding tenders should carry lead lines, buoy cranks, marking buoy, sextant, record book, and signal code. All tenders should be provided with water-tight boxes for holding instruments.

OPERATION OF DRAG.

When the drag is towed through the water it is obvious that a certain strip, bounded on either side by the paths of the large end buoys, which are directly over the ends of the drag, is covered; and that any obstruction between the end buoys extending above the plane described by the bottom wire will interfere with the progress of the drag (figs. 1 and 10). To survey a certain area it is necessary to completely cover the area with a system of overlapping strips, with drags set at suitable depths, so that all obstructions therein will be discovered, or it will be proved that the area is free from such obstructions. To operate efficiently the apparatus described in the preceding pages the following are necessary:

1. A trained organization of officers and men.
2. Suitable instruments for obtaining and plotting the paths of the drag and locations of all obstructions found.
3. A smooth sheet on which can be plotted the drag strips, obstructions found, and effective depths obtained; and a similar sheet for use on the guide launch for controlling the movements of the drag and depth changes.
4. Tide predictions to show the approximate stage of the tide at any time; and all available data regarding soundings in the area to be surveyed.

DEPTH OF DRAG.

Drag depths on the Atlantic Coast are referred to the plane of mean low water. It is considered that an examination to a depth of 50 feet at mean low water is sufficient to insure safe navigation for surface vessels, while an examination to 100 feet is necessary to safeguard submarine navigation. The policy of the Survey is, therefore, to drag deep-water areas to 100 feet or over; to drag areas with depths between 100 and 50 feet to within 10 or 20 feet from the bottom; and to drag areas with depths less than 50 feet to within about 3 feet from the bottom.

When the drag is towed through the water the bottom wire will usually lift slightly. The amount of this lift, which is rarely over 2 feet, is determined by tests conducted from the tender. For this purpose a tester is used which consists of a one-half inch brass rod about 3 feet long attached to one end of a small chain. This rod and chain is graduated in the same manner as a lead line, the chain being used to insure an invariable length. The tender stops a short distance ahead of the drag, opposite the point to be tested, and lowers the tester to a depth about equal to the upright length. When the wire strikes the rod the tester is lifted until it clears the wire, and the difference between the upright length and the reading of the tester when it clears gives the lift.

To obtain the upright setting for a certain effective depth it is necessary to add to this depth the lift correction and the height of the tide above mean low water as shown by predictions which are usually furnished in the form of a curve to a suitable scale. While predicted tides are used for setting the drag, the final reduction is made by using observed values obtained during the course of the work on a near-by gauge.

In channels and in deep water the drag is usually set to one depth throughout, and for the latter work it is customary to avoid depth changes by setting the drag for the maximum height of tide that will occur during the day. In shoal water fairly long drags can be used by setting the drag at different depths to conform to the bottom contour as shown by soundings. In this class of work frequent depth changes are necessary in order to allow for rise and fall of the tide, to conform to changing bottom contours, and to avoid shoals previously discovered. In this class of work it is not considered good practice to have the difference in length between adjoining uprights greater than one-fortieth of the distance between them.

ORGANIZATION.

The usual party organization is as follows: Guide launch, 3 officers, marine engineer, recorder, coxswain, line tender; end launch, 1 or 2 officers, engineer, coxswain, line tender; tender, drag master, engineer; sounding tender, 1 officer, engineer.

SMOOTH AND FIELD SHEETS.

The smooth sheet is similar to the sheet used for ordinary hydrographic work. It has a polyconic projection on a scale depending on the nature of the work. For shoal-water work scales of 1:10,000 and 1:20,000 are commonly used, while for deep water scales of 1:30,000 or 1:40,000 may be used. The positions of all objects used for control are shown on the sheet. The field, or boat, sheet is similar to the smooth sheet and contains in addition a compass rose, with 10-degree divisions, a scale of statute miles, and complete data regarding soundings. These soundings are conveniently entered in feet with black ink, while depths on shoals found with the drag are later entered with red ink. Another method is to show all soundings on a transparent celluloid tracing of the boat sheet.

SETTING OUT DRAG.

On the way to the working grounds the starting point for the day's work is decided upon and a line is drawn on the boat sheet representing the desired path of the large buoy nearest the guide launch. A line parallel to this, at a distance depending on the drag length that is to be used, is drawn to represent the path of the end launch large buoy. It is always best to drag as fair with the current as possible. When dragging against or across the current, not only is progress retarded but there is likely to be considerable variation and uncertainty in the lift. In regions where there is very little current this practice is not so important. The heights of tide at hourly intervals during the day are tabulated and the uprights are set, the free cable being coiled near its buoy. The upright length and initial course in degrees are signaled to the end launch.

The drag is usually set out from the launches while under way. Arriving at the starting point, the guide launch heads, at slow speed, on a course about at right angles to the path lines. Two floats are attached to the end of the bottom wire and it is passed overboard through the after guide. In setting out, the officer in charge maintains a general supervision and directs the course of the launch, another officer operates the reel, the third officer assists with the buoys and checks each upright setting as it passes overboard, the engineer operates the engine and steers the launch, one hand attaches floats, another attaches weights, and the remaining hand tends the buoys. At each connection the reel is stopped while a float is attached. While setting out a section, the end of an upright is passed through the guide to a hand, who inserts the open staple of the weight through the swivel at the end of the upright. When the last float of the section is attached, the clutch of the launch engine is thrown out, and, at the next connection, the reel is stopped while a weight and upright are attached by inserting and locking the staple through the link. The launch then goes ahead and a hand holds the upright until it uncoils, after which the buoy is thrown overboard. These operations are repeated until all the bottom wire is out. The bottom wire is then disconnected, and the free end on the reel is made fast, while the other end is shackled to the staple on the large weight. The towline is then unreeled, so that the end of the lower part of the bridle can be shackled, together with the lower end of the large buoy upright, to the end of the rod on the large weight. The end of the upper part of the bridle, to which a snap hook is shackled, is attached to the large buoy. The large weight is then lowered overboard, by a rope bight through the staple, until the strain comes on the towline, the reel being securely braked. The reel is then allowed to turn slowly while the upright runs overboard. It is stopped while the large buoy is thrown overboard and then released again until the strain comes on the buoy. When everything is clear of the propeller, the launch goes ahead, while the towline is set out. Two floats are attached at each connection except at the end of the bridle, where three are used. At the end of the towline a buoy of sufficient size to support the end on the surface is attached. The steel and rope towlines are then connected and the launch is ready to start dragging. The various connections are shown in figure 9.

After about two sections of the drag are set out, the end launch picks up the end of the bottom wire. If this launch is to set out any bottom wire, it is done in the same manner as on the guide launch; otherwise the end of the wire is shackled to the large weight and the large buoy and towline is set out, after which the officer in charge signals that the launch is ready for dragging.

During the early stages of setting out, the drag is likely to change its position considerably, and some experience is required to select the starting point in such a manner that the drag will be in proper position to start dragging. After two or three sections are out the wire and buoys offer considerable resistance and the speed of the launch may be increased.

The above method of setting out can not be used to advantage in narrow channels or in shoal areas where there is considerable current. In these cases it is best to anchor the launch at one end of the path line and let the tender tow out the bottom wire, stopping and starting on signal when the weights are attached.

DRAGGING.

After the drag is set out the launches proceed on their initial courses. It is obvious that each launch must head out from the path-line course, the difference in course depending on conditions. When towing with very little current, each launch may head out 10 or 20°, while in strong currents the difference is considerably increased. Towing speed is also an important factor. The maximum practicable speed of drag is, of course, desirable, but if the speed is excessive the lift is likely to increase and the small buoys tow under so that depth changes can not be made. To adjust speed for various conditions calls for considerable judgment, and no fixed rules can be laid down. As general guides, however, it may be stated that a 40-horsepower engine will usually be run at one-third speed for a 3,000-foot drag, increasing to full speed for longer drags, and that the speed should not be so great as to cause the small buoys to tow under.

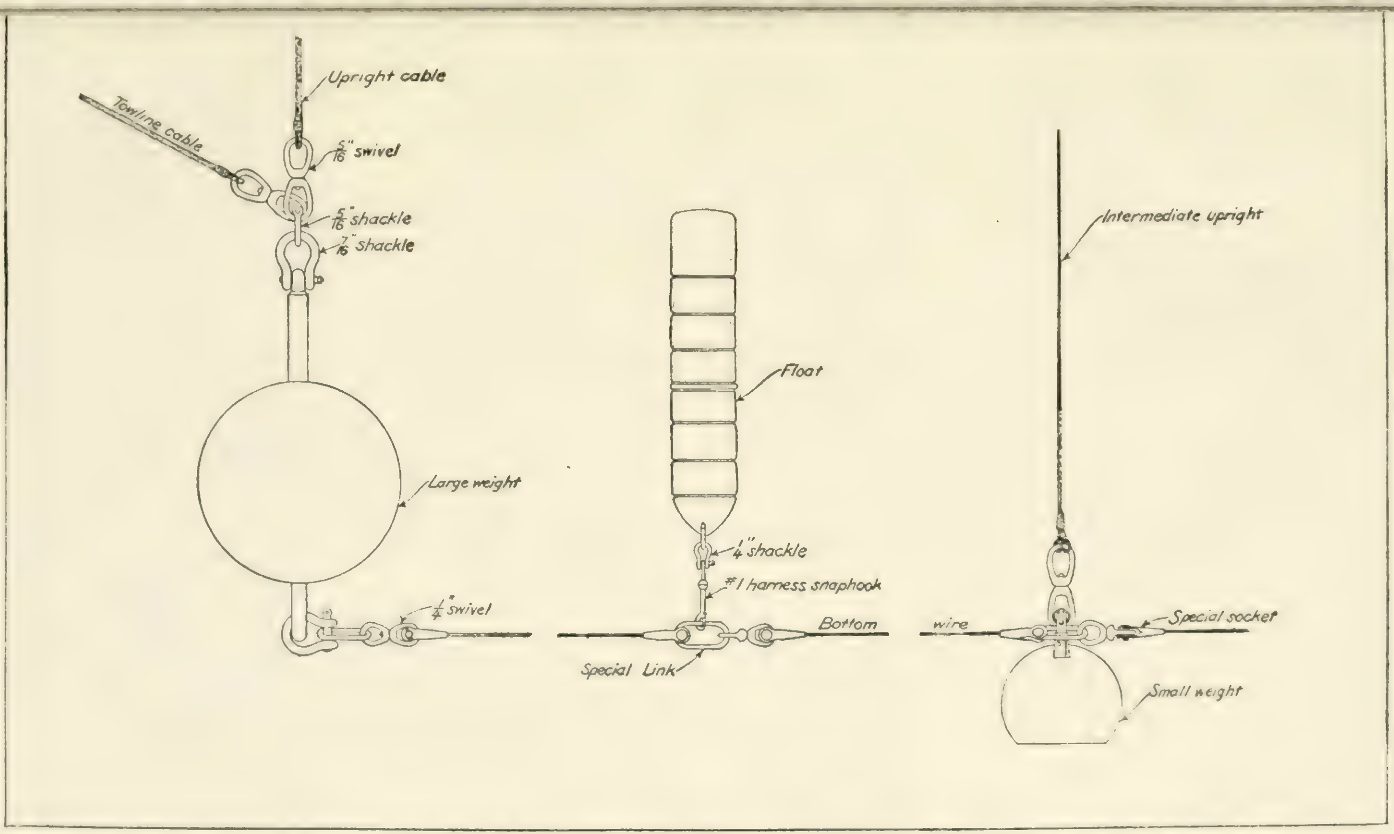


Fig. 9.—METHOD OF MAKING CONNECTIONS.

The tendency to lift will decrease as the proper effective drag width is approached, and a gauge for this width is obtained by laying down the path lines at a suitable distance apart. The most efficient effective width will usually be about 90 per cent of the total length of drag.

As the drag proceeds, its position from time to time is obtained by methods that will be described herein. After each position necessary alterations in the course to keep the drag on its path can be made. The drag depth is tested as frequently as practicable. When towing against or across the current, the frequency of tests should be increased. Depth changes are made by the tender on signal. In making such changes care must be taken to approach the buoys on the course that they are making and to keep headway on the tender so that it will not drag on the upright and lift the bottom wire.

The drag master, in charge of the tender, is responsible for considerable important independent work, and should be the most experienced and skillful hand in the party. After patrolling and testing the drag he will be able to give the officer in charge valuable suggestions concerning towing speed, current conditions, etc.

The drag proceeds in this manner until a shoal is found or the end of the line is reached. In the latter case the drag may be taken up or reversed to cover an adjoining strip. If for any reason tension is removed from the wire, the floats tend to lift the wire and the line ends. It should be noted that the path lines need not be straight, for with proper management the drag can be turned at any angle desired. When covering an area with overlapping strips, small areas, called "splits," may remain uncovered, due to temporary loss of control when overlapping, discovery of shoals, or drag failure. It is best to leave these splits until the work is nearly ended, for several of them may be close together, so that time can be saved by covering them with one set-out.

CONTROL.

Drags 6,000 feet and under in length are controlled from the guide launch, the control system being shown in figure 10. The position angles, R and L, between located objects are measured simultaneously with sextants by the first officer, who is in charge, and the third officer. The first officer then plots the position of the launch by means of the standard 3-arm protractor, while the third officer measures the angles N′ and F′, the angles from one located object to the near and far large buoys, respectively. The first officer then uses a special instrument, called a wire-drag-position protractor, to plot the position of the near large buoy by laying off its bearing and distance, the latter being the towline length (O to N in the diagram). While this work is going on the second officer signals to the end launch and measures the angle A, and the officer on the end launch, on receipt of signal, measures the angle S and signals it, in degrees and tenths, to the guide launch. Knowing the length of the towline base O′ to F and the angles A and S, the second officer can compute the distance O to F on a special circular slide rule called a wire-drag computer, and the position of the far large buoy can be plotted with the position protractor. Only a short space of time is required by skilled observers to obtain a complete position. Positions are taken at regular intervals of from 2 to 10 minutes, depending on the nature of the work, and successive positions of each buoy are connected by straight lines representing the paths of the buoys.

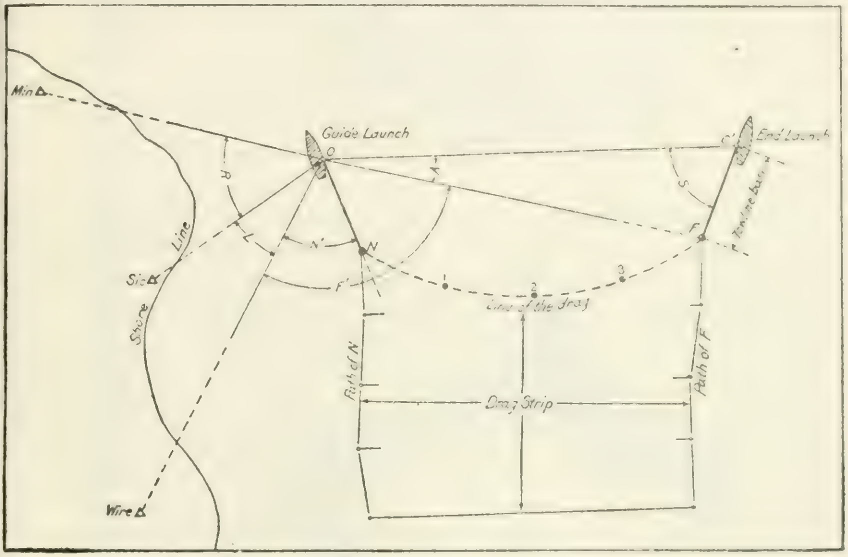


Fig. 10.—GUIDE LAUNCH CONTROL SYSTEM.

With this system of control all angles must be measured very carefully, and proper care must be taken to avoid obtaining distances under unfavorable conditions, as when the end launch is heading nearly toward or away from the guide launch. It is also best to introduce a factor of safety by using a base less than the actual length of towline. The actual length of the rope towline and a 300-foot steel towline is about 102 meters, while for computation it is considered to be 100 meters. The towline base should be checked at least once during the season by observing simultaneous position angles on the end launch.

Except in narrow channels, the length of the steel towline need not be less than 300 feet, with a 100-foot bridle and a 200-foot straightaway. For deep drag work it is best to add a 100-foot towline unit to the upper and lower parts of the bridle, and with a 6,000-foot drag the towline base should be increased to 500 feet (considered to be 160 meters for computation) by adding a unit to the straightaway. As it is sometimes difficult to see the far large buoy from the guide launch, it is customary to attach a watch buoy (fig. 5) so that it will tow 2 or 3 feet behind the large buoy. This buoy may conveniently consist of a bamboo pole or iron pipe, with a flag or banner at the top, supported at the middle by a can and counterweighted at the bottom so that it will float upright.

For long drag work each launch is supplied with a boat sheet on which is drawn the path of its large buoy. Position angles and the angle to the nearest large buoy are observed and plotted on each launch. All details are arranged beforehand, so that very little signaling is necessary. As a final factor of safety, all overlaps should be made ample.

The time used by the tide observer should be checked at the beginning of each day, if practicable, and the time used by the subordinate launches should be compared with guide-launch time several times during the day.

Three special instruments are used for plotting wire-drag work, the position protractor, the computer, and the buoy spacer. The protractor (fig. 11) consists of three rings, the lower one of which is of brass and carries the bearing surface and an extension arm. The upper ring, of German silver, is graduated to degrees (clockwise from 0 to 360° and counterclockwise from 0 to 180°) and is attached to the lower ring. Between the upper and lower rings a narrow brass ring, with two cross spokes at right angles, turns freely. One of the cross spokes carries the center, the index, and a removable scale corresponding to the scale of the sheet. To plot the position of a buoy, the center is placed over the boat position, the edge of the extension arm is placed over the position of the reference object, and the index is set to the angle, to the right or left of zero, corresponding to the bearing of the buoy. The position of the buoy is then plotted along the edge of the scale at the proper distance from the center.

The computer (fig. 11) is a circular slide rule consisting of two circular disks, two indicators, and a center clamp nut so arranged that the upper indicator can be clamped to the upper disk, leaving the lower indicator and disk free to rotate around a common center. Based on the fact that the sides of a triangle are proportionate to the sines of their opposite angles, the five concentric arcs are so graduated that the instrument can be used to compute the distance from the guide launch to the far large buoy when the angles and towline length, previously described, are known. All linear distances are given in meters. The method of operation (numbering the arcs

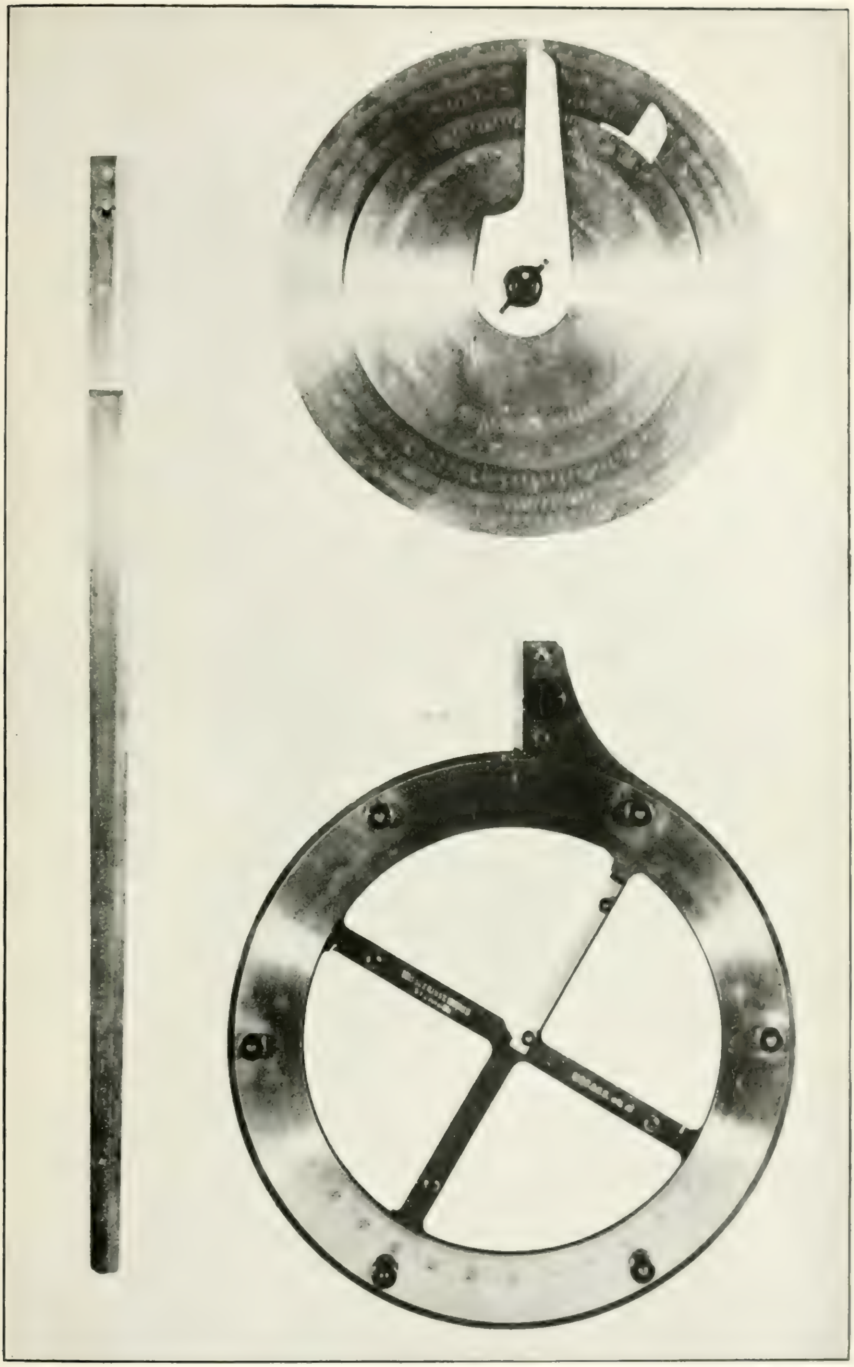


Fig. 11.—WIRE-DRAG PROTRACTOR AND COMPUTER.

from 1 to 5, from the center toward the outside edge) is as follows: Set upper indicator at proper length of towline base on arc 1 and clamp. Turn both until indicator is against the distance angle (angle A, fig. 10) on arc 5 for angles 5° 44′ or less and on arc 3 for larger angles. Holding the disks together with one hand, turn the lower indicator to the signaled angle (angle S) on arc 2. The distance is then given by the lower indicator on arc 4.

The buoy spacer (fig. 12) is used to show the position of each intermediate buoy and the line of the drag, which curves between the end buoys, at any time, as at the end of a line, when tidal changes alter the effective depth or when depth changes are made. The spacer used in the field consists of a celluloid strip about one-half inch wide, on which two full lines, at a suitable distance apart, depending on the scale and drag length, representing the end buoys. The space between these lines is divided into a suitable number of equal spaces, each representing a section, by shorter lines, each of which represents an intermediate buoy. To use this spacer, it is only necessary to bend the strip so that it will curve in the proper direction with each end buoy line, touching the position of its corresponding buoy, as shown by the buoy path lines. The edge of the curve against the sheet will then show the line of the drag, while the position of each intermediate buoy will be indicated at the point touched by its corresponding line. A special strip must, of course, be provided for each standard length of section.

For office work a more accurate spacer has been devised and constructed of durable materials. This instrument consists of an arm rigidly attached at right angles to a strip on which a second arm, parallel to the first and provided with set and tangent screws, slides freely. The outer end of each arm is provided with a swivel plug for holding each end of a scale graduated in the same manner as the celluloid strip. The holder is of brass and the scales of thin steel. This instrument can be set for any curve, and will lay on the smooth sheet at any desired position.

SIGNAL SYSTEM.

For efficient control of wire-drag work a very complete signal system is necessary. Directions from the guide launch are sent with the semaphore machine. The end launch (if not provided with a semaphore machine) and the tenders use wigwag flags. The large tender is provided with a black flag for sending letters and a black and white flag for numbers, while the other boats use red flags for letters, and red and white for numbers. The Morse code is used for letters, and a special code has been devised for numbers. This code is as follows, the dot and dash being represented by the figures 1 and 2:

1.—1; 2.—2; 3.—11; 4.—22; 5.—12; 6.—21; 7.—111; 8.—222; 9.—122; 0.—221

As special flags are used for numbers, there is no possibility of confusion.

For brevity in directing and recording, the large end buoy nearest the guide launch is designated by the letter N, the far large buoy by the letter F, while the intermediate buoys are numbered consecutively, beginning with the buoy nearest the guide launch as number 1 (fig. 10). Each launch is assigned a letter and each standard operation or maneuver is represented by a letter or a combination of two letters. The various semaphore positions, corresponding letter or number, and meaning of each letter for drag work are shown in figure 13. The letters are in accordance with the standard Navy code, but the numerals are specially assigned. In selecting machine positions for the numerals it is desirable to avoid using the positions corresponding to the letters N and F, the large buoy designations or positions corresponding to letters that have a special significance to the end launch, such as "Stop" or "Take up drag." To avoid confusion the end launch should not call the tenders except in emergencies. If the services of a tender are needed, the fact should be made known to the guide launch.

MANAGEMENT ON SHOALS.

When the drag, proceeding with a fair tide, catches on a shoal the effect is noticed very quickly on the towing launches. They lose headway, swing in, and in a very short time the buoys will begin to line up and point toward the shoal. If the drag grounds near the end launch, the effect may first be noticed there, or the tender may observe the grounding when patroling the drag. In these cases the launch that first observes the grounding reports to the guide launch and awaits instructions. The towing launches stop and the tenders proceed to the indicated location of the shoal, where they sound with lead and line until a depth less than the upright length is found. A marker buoy is then set, care being taken that it is placed back of the bottom wire, and the large tender, on signal, clears the drag and the work proceeds. The sounding tender remains on the shoal until the officer in charge is reasonably sure that he has found the least depth, after which he locates the shoal by position angles, describes it carefully, picks up the marker buoy, and rejoins the towing launches. Position angles on shoals should be checked by an angle to a fourth object or by measuring the sum of the two position angles. The description of the shoal should be as complete as possible and should include the nature of the obstruction, its general shape and extent, and the general surrounding depth.

When proceeding against the current the action of the drag on a shoal is not so satisfactory. The buoys will not line up so quickly and, if the launches stop, the drag is likely to drift back from the shoal. In this case it is usually best for the towing launches to go ahead very slowly until a tender can place a buoy at the indicated position of the shoal.

The drag will sometimes catch on wreckage or other obstruction of such small extent that a sounding can not be obtained. In this case, after a reasonable length of time, the drag is cleared, a position is taken, and all available data is recorded, the upright length being considered as the depth on the obstruction. All shoals are later covered with a drag set 2 or 3 feet less than the depth found, to make sure that this is the least depth.

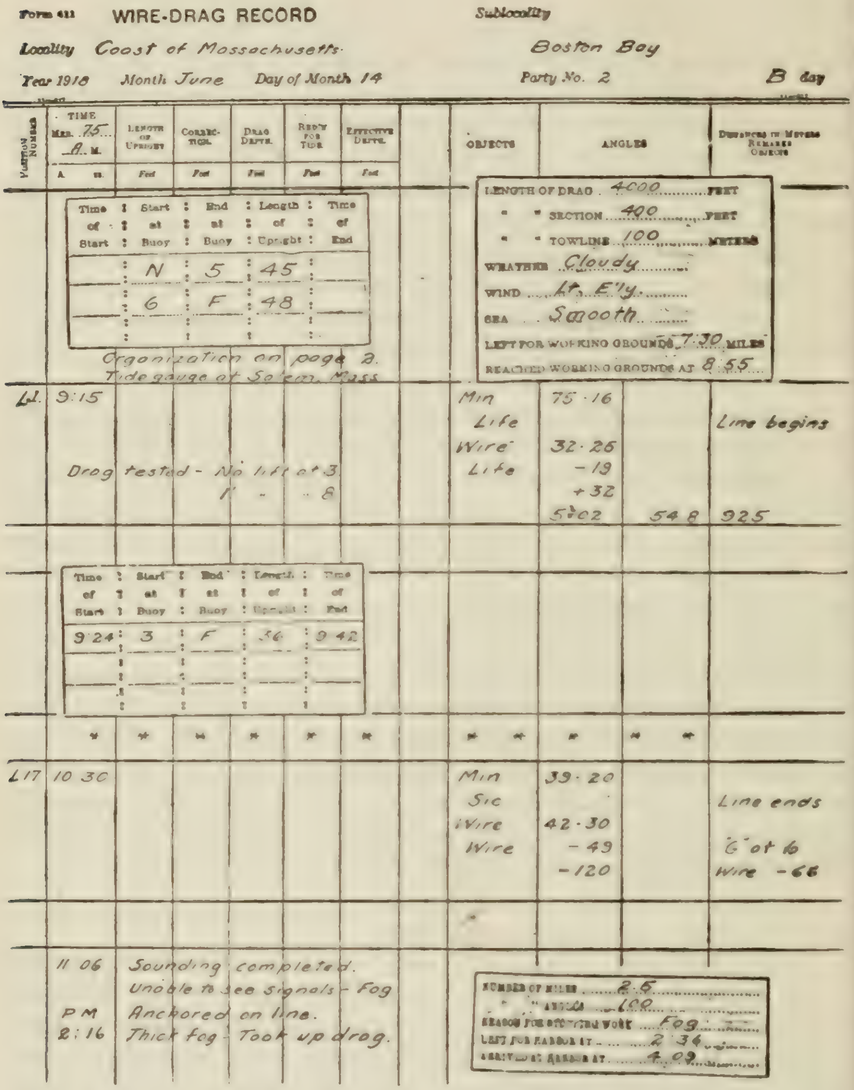
It should be noted that a smooth, small-grained material, such as mud, sand, or gravel, will not necessarily stop the drag, while rock or any hard obstruction will stop it instantly. The drag can be used to find mud or sand shoals by placing the buoys fairly close together and watching the drag closely for overturning of buoys.

To clear the drag the tender usually lifts the bottom wire near the shoal with a grapnel or by hauling up an upright, takes it across the bow, and goes ahead toward the shoal. Frequently the wire comes clear during the process of underhauling. If caught too hard for this the wire is made fast at the bow and the tender proceeds under power to break it out from the bottom. If this method fails the wire may be disconnected and hauled clear or a portion can be abandoned. If the shoal is extensive the sounding tenders may hold up the wire at different points or the uprights may be shortened until the drag is clear. While the drag can usually be cleared, time in some cases can be saved by taking it up. After the wire is clear the tender holds it up with a rope bight at the bow and signals to the towing launches to go ahead. When changing ranges or soundings show that the shoal is passed the tender drops the wire and reports to the guide launch, so that the line can be started.

RECORDS.

All operations and angles in wire-drag work are recorded for final preservation and for later work on the smooth sheet. A separate smooth sounding record and a wire-drag record are kept for each sheet. The end launch officer records, for future comparison, each angle that he signals, together with the time. Each tender records all data obtained on shoals; depth changes, giving the time that the change started and ended, the new depth and the buoys involved in the change; drag tests, etc. All data in regard to shoals is later copied from the tender records into the smooth sounding record on the guide launch, while other information is transferred to the wire-drag record.

The wire-drag record on the guide launch is kept in the following standard form:



Form 411 **WIRE-DRAG RECORD** Sublocality

Locality *Coast of Massachusetts.* *Boston Bay*

Year 1918 Month *June* Day of Month *14* Party No. *2* *B* day

Position Numbers	TIME Mer. *75* *A*. M.	Length of Upright	Correction	Drag Depth	Red'n for Tide	Effective Depth		Objects	Angles		Distances in Meters Remarks Objects
	A. M.	Feet	Feet	Feet	Feet	Feet					

Time of Start	Start at Buoy	End at Buoy	Length of Upright	Time of End
	N	5	45	
	6	F	48	

Organization on page 2.
Tide gauge at Salem, Mass.

LENGTH OF DRAG *4000* FEET
" " SECTION *400* FEET
" " TOWLINE *100* METERS
WEATHER *Cloudy*
WIND *Lt. E'ly.*
SEA *Smooth*
LEFT FOR WORKING GROUNDS *7:30* MILES
REACHED WORKING GROUNDS AT *8:55*

L1.	*9:15*							*Min* *Life* *Wire* *Life*	*75·16* *32·26* *−19* *+32* *5°02*	*54 8*	*Line begins* *925*

Drag tested - No lift at 3
" - - 8

Time of Start	Start at Buoy	End at Buoy	Length of Upright	Time of End
9 24	*3*	*F*	*36*	*9 42*

	*	*	*	*	*	*		* *	*	* *	
L17	*10 30*							*Min* *Sic* *Wire* *Wire*	*39·20* *42·30* *−49* *−120*		*Line ends* *6 ft of 16* *Wire −66*
	11 06 *PM* *2:16*	*Sounding completed.* *Unable to see signals - Fog* *Anchored on line.* *Thick fog - Took up drag.*									

NUMBER OF MILES *2.5*
" " ANGLES *100*
REASON FOR STOPPING WORK *Fog*
LEFT FOR HARBOR AT *2 34*
ARRIVED AT HARBOR AT *4 09*

On the first page of each record are entered the names of objects used for control and the manner in which their locations are obtained, together with the short names assigned to them for convenience in recording. On the second page the party organization is given, with the name and duties of each member. Rubber stamps are provided for insertion of data shown at the top and bottom of the right-hand side of the record. At the upper left hand a stamp is provided for insertion of initial lengths of upright. Whenever a depth change is made during the day, this stamp is used and the blanks are filled in except for the times of start and end, which are obtained later from the tender record. At each position the time, position angles, buoy angles, distance angle, signaled angle, and distance are entered, as shown, in the order named. A buoy angle is considered as plus if the buoy is to the right of the object, and minus if to the left. When the drag catches on a shoal, an excellent check on the shoal position is obtained by observing and recording a bearing to the indicated position, with a note as to the number of the buoy nearest the shoal. It should be noted that, when the drag lines up on a shoal, a final distance to the far large buoy is not necessary, as its position is given by the bearing and the known length of the drag from the near large buoy around the shoal.

Successive days are lettered in order and corresponding days in the wire drag and sounding records are given the same letter. Explanatory notes should be entered, when necessary, in the wire-drag record, and every care taken to make it a clear and complete record of each day's work.

For long drag work positions are recorded on the end launch and later transferred to the right-hand angle column of the guide-launch record.

REPAIRS.

If the engine on one of the towing launches stops for a brief period, the other launch may proceed slowly and, by keeping tension on the wire, avoid ending the line. If the delay is likely to be lengthy, the tender may tow the disabled launch while repairs are being made.

If the drag parts, it may be connected by the tenders towing the broken ends together and inserting a new unit, while the towing launches reverse and converge to lessen the strain on the drag. In some cases it may be expedient for one of the towing launches to drop the towline and help tow the ends together.

SUPPLEMENTAL SOUNDINGS.

In regions where few soundings have been obtained, additional soundings may be obtained from the large tender, which sounds at various buoys, as directed, while the drag is under way and records the sounding, time, and number of the buoy at which the sounding is obtained. As the position of the buoys at any time can be shown on the sheet, each sounding so obtained can later be plotted in its proper position on the smooth sheet.

TAKING IN DRAG.

To take in the drag, the reel engine is started and the launch stops and goes astern a little, so that the end of the steel towline can be hauled aboard. This is detached from the rope towline and attached to a line leading forward over the platform and back to the reel, where it is attached to the towline compartment. The launch then swings and heads toward the large buoy, while the reel is operated at slow speed to take in the towline. As the floats come aboard the reel is stopped while they are detached by a hand at the bow. When the strain of the weight comes on the towline, the large buoy will capsize and, with proper launch handling, will come alongside on the starboard side. The upper part of the bridle is detached from the buoy, and the large weight is then reeled aboard. The buoy is hoisted with the davit, and its upright is hauled aboard as soon as it is detached from the weight. The free end of the towline is then made fast to the reel, while the end of the bottom wire on the reel is unfastened and led forward. The end of the bottom wire is detached from the weight and connected to the free end from the reel, after which the launch heads along the line of the drag while the reel is operated at high speed. The launch should head in such a manner that the wire will lead a little off the starboard bow and should not go fast enough to overrun the wire. As each float and weight comes aboard the reel is stopped while they are detached. The buoys are hoisted aboard on the starboard side and placed in the rack, with uprights coiled out of the way. The end launch takes in drag in the same manner until within about two sections from the guide launch, when she disconnects the bottom wire, leaving the remainder of the drag to be taken in by the guide launch.

On the way in from the working grounds the data in the tender records is copied in the smooth sounding and wire-drag records and checked, signaled angles are compared from the end launch record, and the floats and weights are brought aft in readiness for the next day's work.

SHORE WORK ON DRAG.

There is a sufficient amount of necessary maintenance work on the equipment to keep the party employed during periods when unfavorable weather conditions prevent dragging. For this purpose a workshop and a covered space or wharf of sufficient length to permit stretching of bottom wire, towline units, and uprights should be provided. The maintainance work, which is done under the direct supervision of the drag master, includes the painting of floats and buoys with red lead for protection and to increase the visibility of the latter in the water; frequent repainting of uprights; the preparation of new parts; general repair work on equipment and engines, and the upkeep of the launches.

The party should be provided with an ample supply of ship chandlery, such as 1¾-inch, 15, 9, and 6 thread rope, tarred marline, paints, and oils, etc.; and a complete set of carpenter and machine shop tools, including a grindstone, emery wheel, drill press, blacksmith's forge, anvil, and possibly a small machine lathe.

OFFICE WORK.

The office work on shore includes the necessary accounting in connection with the finances of the party, reduction of records, plotting on the smooth sheet, and miscellaneous work. For this work a well-lighted office of sufficient size to hold two drafting tables, a desk, one or two office tables, and a chart rack should be provided if practicable.

REDUCTION OF RECORDS.

To reduce the records (see sample page of record), the upright length is entered in the proper column at the top of each page and where it is changed by a depth change. The correction, as shown by tests, is entered and subtracted from the upright length to obtain the drag depth. If there is a correction for swell it will be noted by the officer in charge and will be added to the correction. For deep drag work a factor of safety may be introduced, at the discretion of the chief of party, by adding a foot or two to the lift shown by tests. Tidal reducers are entered in the same manner as for ordinary hydrographic work and applied to the drag depth to give the effective depth. If the tidal change occurs between two positions, it is shown at the preceding position if it decreases the effective depth, and at the succeeding position if the contrary is true. All distances must be checked by recomputation.

At the end of each day in the record an effective depth diagram is entered. This diagram, which is simply a summary of all effective depths obtained during the day, is entered in the following form:

Position		Remarks
1	$N \overset{43}{\text{-----}} 6 \overset{45}{\text{-----}} F$	B
2.8–6.4	$2 \overset{34}{\text{------}} \overset{\rightarrow}{\text{------}} F$	
8	$N \overset{44}{\text{-----}} 2 \overset{35}{\text{-----}} F$	Tide

The first entry shows the initial effective depths, the letter B indicating that the line begins. It should be noted that no effort is made to show the depths of an inclined section between two different upright lengths. The lesser depth is considered as extending horizontally to the first upright set at a greater depth. Thus at the beginning of the day the path of buoy No. 6 is the dividing line between depths. If the difference between the upright lengths had been greater than one-fortieth of the length of section, the lesser depth would be extended over one more section and the path of buoy No. 7 would be the dividing line. The second entry shows the depth change made in the direction of the arrow. As the depth is decreased the change extends automatically to buoy 2 as soon as buoy 3 is changed. The fractional position numbers show that the change started between positions 2 and 3 at a time when buoy No. 3 had traversed 0.8 of the distance between the two positions, and that it ended when buoy F had traversed 0.4 of the distance between positions 6 and 7. At position No. 8 an increase of 1 foot in the effective depths, due to tidal decrease, is indicated.

When the drag parts, care should be taken to eliminate uncertainty by the rejection of a sufficient number of positions.

WORK ON SMOOTH SHEET.

For plotting, the smooth sheet is protected by tracing cloth held securely in place, with small holes cut through over each control object position on the sheet. A number of boat positions are plotted, after which the buoy positions are plotted and pricked through on the smooth sheet. The successive buoy positions are connected by straight lines, using a pencil hard enough to indent the smooth sheet. Care must be taken to plot the buoy positions within a reasonable time after the boat positions lest the tracing changes its position with relation to the sheet. The tracing is then removed while the path lines are drawn in pencil on the smooth sheet. Every fifth position is indicated by its number and the letter of the alphabet assigned to the day, using ink of one certain color. These numbers should be entered only on the guide-launch side of the strip. The curved line of the drag is drawn at the end of each strip, using the buoy spacer. The positions of all shoals discovered during the day are plotted, either immediately before or after plotting the day's work, and numbered as for the drag positions. When a drag strip ends on a shoal, care must be taken to extend the line of the drag back of the shoal.

After the various strips are plotted in pencil they are subdivided to show effective depths by the method indicated in figure 12. For changes due to tide the line of the drag is drawn with the spacer at the proper point. Depth changes are shown by connecting, with a line, the position of the first buoy involved at the time the change started and the similar position of the last buoy changed. If the change affects less than half the drag, the two positions are connected by a straight line. If more than half the drag is changed, it is best to locate the middle buoy involved at the time it was changed, assuming a uniform rate of change, and to connect the three points with a smooth curve. With a drag set at different depths, the dividing lines are obtained by plotting the positions of the dividing buoys at each drag position and connecting succeeding buoy positions with straight lines.

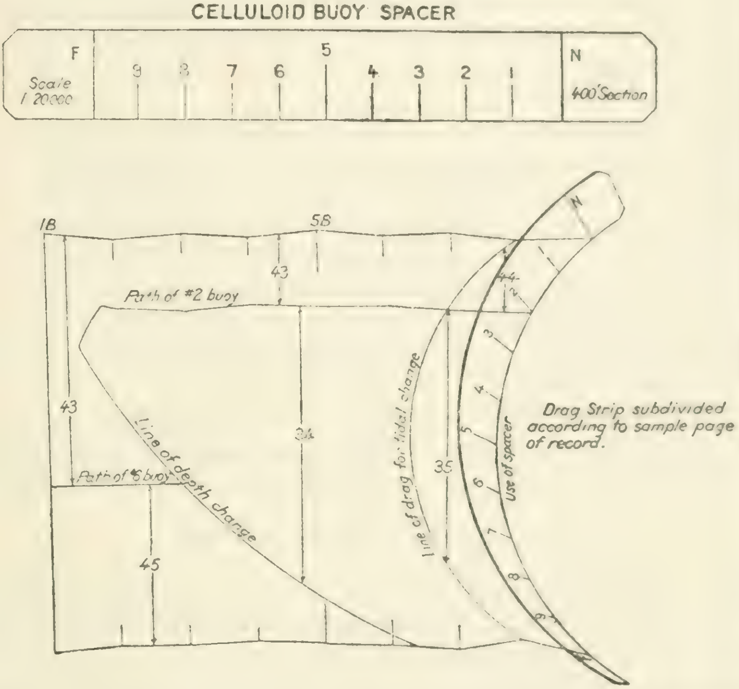


Fig. 12.—BUOY SPACER AND SUBDIVIDED DRAG STRIP.

After a strip is subdivided each subdivision is outlined with colored ink in accordance with the following color schemes, and with the rule that deeper areas are completely surrounded with a line of the proper color, while areas of less depth are surrounded by the proper color, except where they adjoin an area of greater depth:

19 feet and under	Brown.
20 to 29 feet	Yellow.
30 to 39 feet	Blue.
40 to 59 feet	Red.
60 to 79 feet	Purple.
80 feet and over	Orange.

Each area has one or more light lines extending across it, with a space for a numeral representing the difference between the effective depth and the color base. Thus an area dragged to 94 feet will be surrounded with an orange-colored line and contain the numeral 14. In figure 12 the full depths are indicated by the numerals, as the surrounding colors are not shown. When the strips are inked, corresponding positions of *N* and *F* are indicated by short lines drawn from each toward the other. Each fifth position is indicated by slightly longer lines.

In shoal localities, where an area may be covered several times by drags set at different depths, the subdivision described above may be simplified by tracing each strip as it is plotted, subdividing the strip on the tracing and then transferring the subdivisions to the smooth sheet.

The foregoing system of indicating drag depths is superior to any method that has been used before. While it involves two assumptions that are not always true—namely that the greatest ordinate of the drag curve is at the middle and that the rate of depth change is uniform—any small inaccuracies are more than offset by the greater economy secured by the use of a long drag in shoal areas. It is necessary to use judgment in special cases and to perform each operation very carefully. Any discrepancies should be noted and referred to the chief of party.

Rubber stamps covering each operation of reduction and plotting, with spaces for the initials of the persons making and checking such operations, are provided for insertion at the end of each day in the record.

SPEED AND AREA COVERED.

The rapidity with which an area can be examined is one of the most valuable features of wire-drag work. The average speed of the drag in waters where there is no current is about 1½ miles per hour, and it requires from 15 to 20 minutes to set out or take in a 4,000-foot drag. The time required for longer drags is not correspondingly increased, as a considerable part of the time involved is required to set out and take in the large weight, buoy, and towline.

In deep water, where long drags can be used, an area of 10 square miles is frequently covered in a single day, while during the past season, in a region where the currents are strong, an area of 25 square miles was dragged in one day. In shoal areas the area that can be dragged in a day is considerably reduced and may be less than 1 square mile if numerous shoals are found. During one day's work in Florida in 1913 a wire-drag party discovered 15 separate shoals. In regions where the shoal and deep-water work are about evenly divided an average of about 3 square miles may be expected for each full working day during a season.

Ma- hine	Letter Number	Meaning	Ma- chine	Letter Number	Meaning
	A 1	Take angle (to E.L.)		O	Out 10 degrees. (away from G.L.)
	B 3	Begin		P	Drag parted.
	C 5	Repeat last message, or angle.		Q 6	Dead line.
	D	Take up drag.		R	Turn back after next position, if "B" is not given before.
	E 7	Launches change ends of drag.		S	Stop.
	F	Far large buoy. Faster (to E.L.)		T	Anchor.
	G 9	Drag aground; Stop.		U	Attention. I understand.
	H 2	G.L. call letter.		V	Stopped by engine trouble.
	I	In 10 degrees, (towards G.L.)		W	Wait. Stop till further signal.
	J 4	Annul last message.		X 8	Lobster pots. Remove lobster pots.
	K	E.L. call letter.		Y	G.L. Small tender. Call letter.
	L	Slower.		Z 0	E.L. small tender. Call letter.
	M	Large Tender. Call letter.			Change letters to numbers or vice versa.
	N	Near large buoy.			Course follows in degrees from 0 to 360.

COMBINATIONS.

U-B	Connect drag by towing broken ends together.
U-C	Clear drag to continue line.
U-C-R	Clear drag to reverse line.
U-D	Disconnect drag. (to tenders only)
U-H	Underhaul drag to locate shoal.
U-M	Measure towline base.
U-R	When drag is parted, reverse and head in to aid tenders.
U-S	Send least water found on shoal.
U-T	Test drag depth.

Fig. 13.—WIRE-DRAG SIGNAL CODE.

COST OF WIRE-DRAG WORK.

The costs of wire-drag work vary through a wide range and are affected by numerous conditions. On the coast of New England, for example, fishing gear, such as lobster pots and trawls, interferes with the work and must be removed. To effect this, it is necessary to divide the area to be dragged into small sections and to drag each section separately. When a section is to be dragged, its corners are buoyed and fishermen are notified, so that they can remove their gear. This procedure prevents the planning of work to take advantage of different weather and current conditions and adds greatly to its cost. Likewise, in narrow channels, the length of drag is limited, and in many cases the currents are so strong as to prevent work except at or near slack water. In all regions the cost increases with the number of shoals that are found. To illustrate the difficulty of giving a clear idea concerning the cost of drag work, it may be stated that in 1915 a wire-drag party surveyed an area of 135 square miles in Cape Cod Bay at a cost of $90 per square mile and that later in the season the same party surveyed 1.7 square miles in the East River, N. Y., near Hell Gate, at a cost of $1,200 per square mile. This subject is discussed more fully in Special Publications Nos. 29 and 34.

CONCLUSION.

While the elaborate apparatus, operating equipment, and special launches described in the preceding pages have been perfected for the purpose of increasing the efficiency and consequent economy of wire-drag work, it should be remembered that the principle of the wire-drag is very simple and is always available to the hydrographer. Lacking special equipment, a drag can be improvised for work of small extent by using material at hand, such as telephone or sounding wire, oil cans, sounding leads, etc., and operated in fair weather from whatever launches are available.

The use of such equipment will not be entirely satisfactory, but it can not fail to be of value in all cases where such a device is needed.